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(54) CAM SHAFT DRIVE FOR ENGINE

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(58) **Field of Search** 123/90.15, 90.16, 123/90.17, 90.18, 90.31

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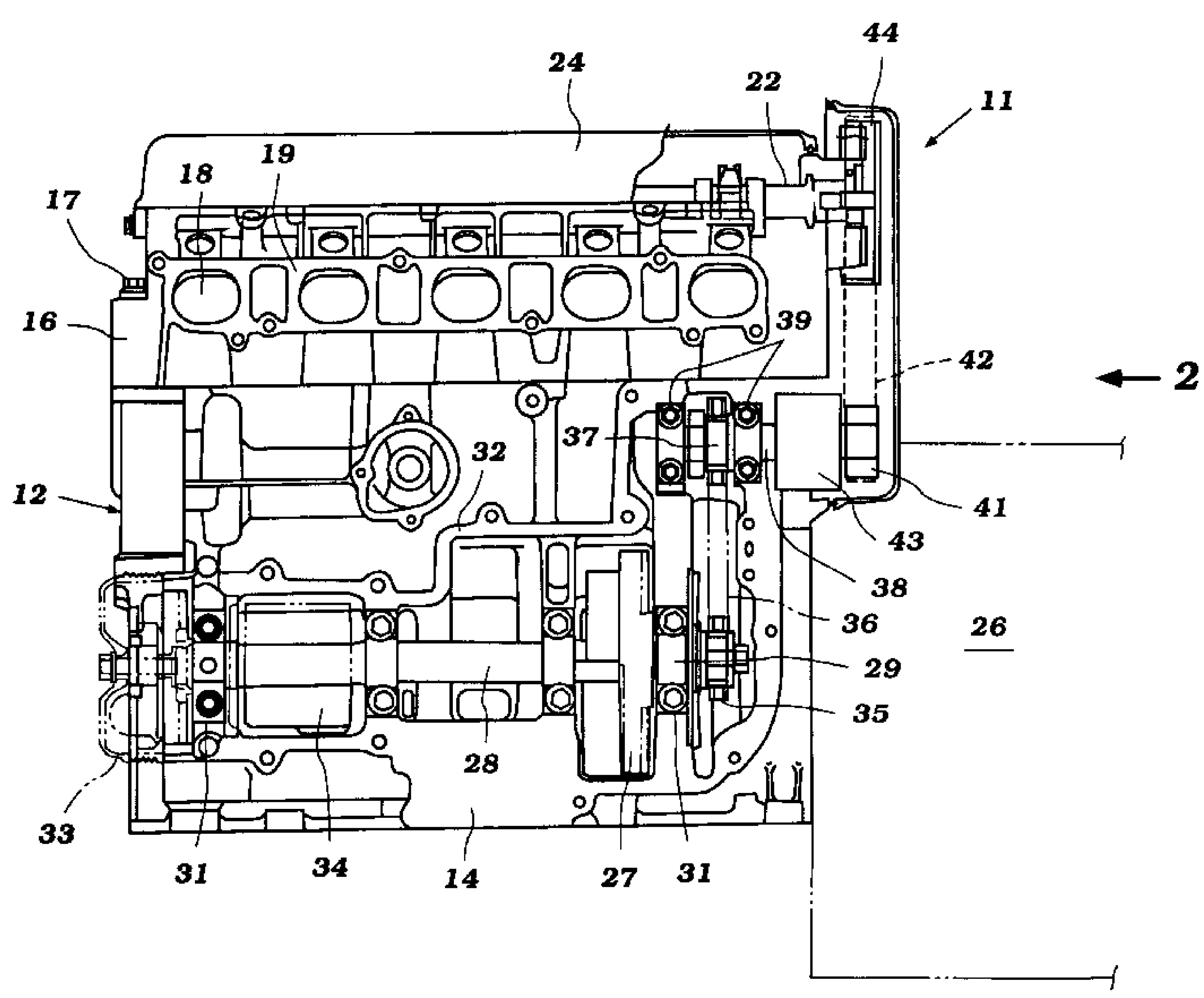
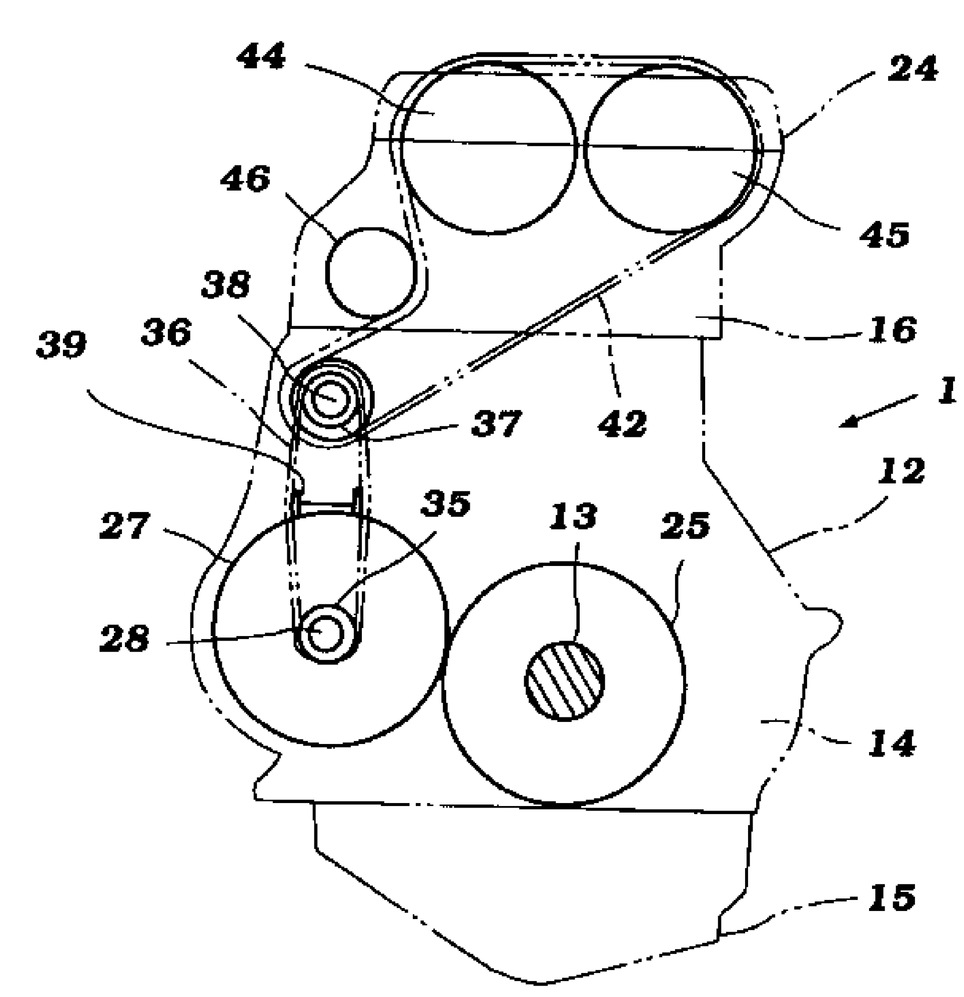
(57) **ABSTRACT**

A number of embodiments of internal combustion engines that embody a variable valve timing mechanism for varying the valve timing during engine operation. The variable valve timing mechanism includes at least one VVT device that is located at a position that is remote from the cam shaft and in each embodiment is mounted in the cylinder block.

16 Claims, 4 Drawing Sheets





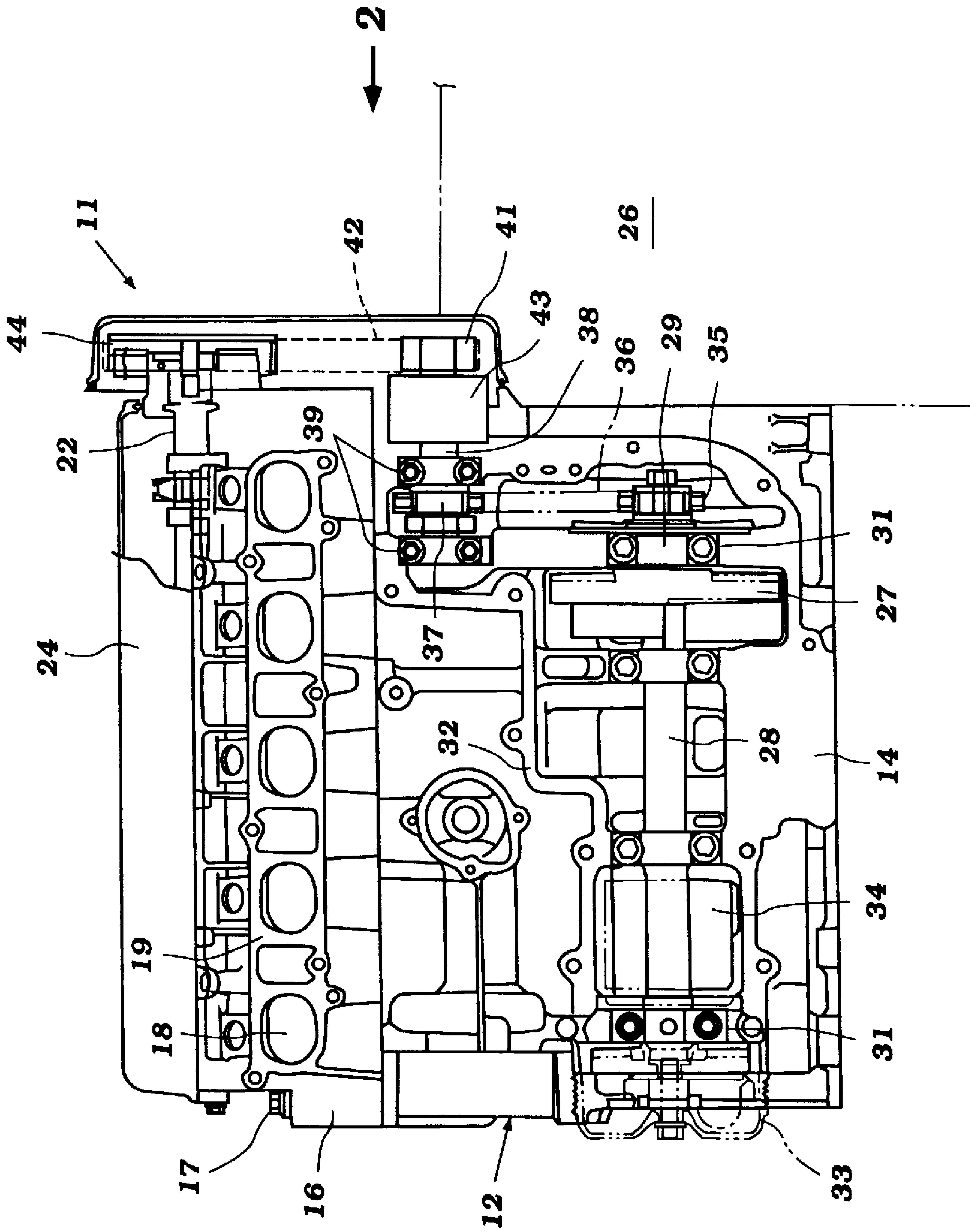

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Figure 1

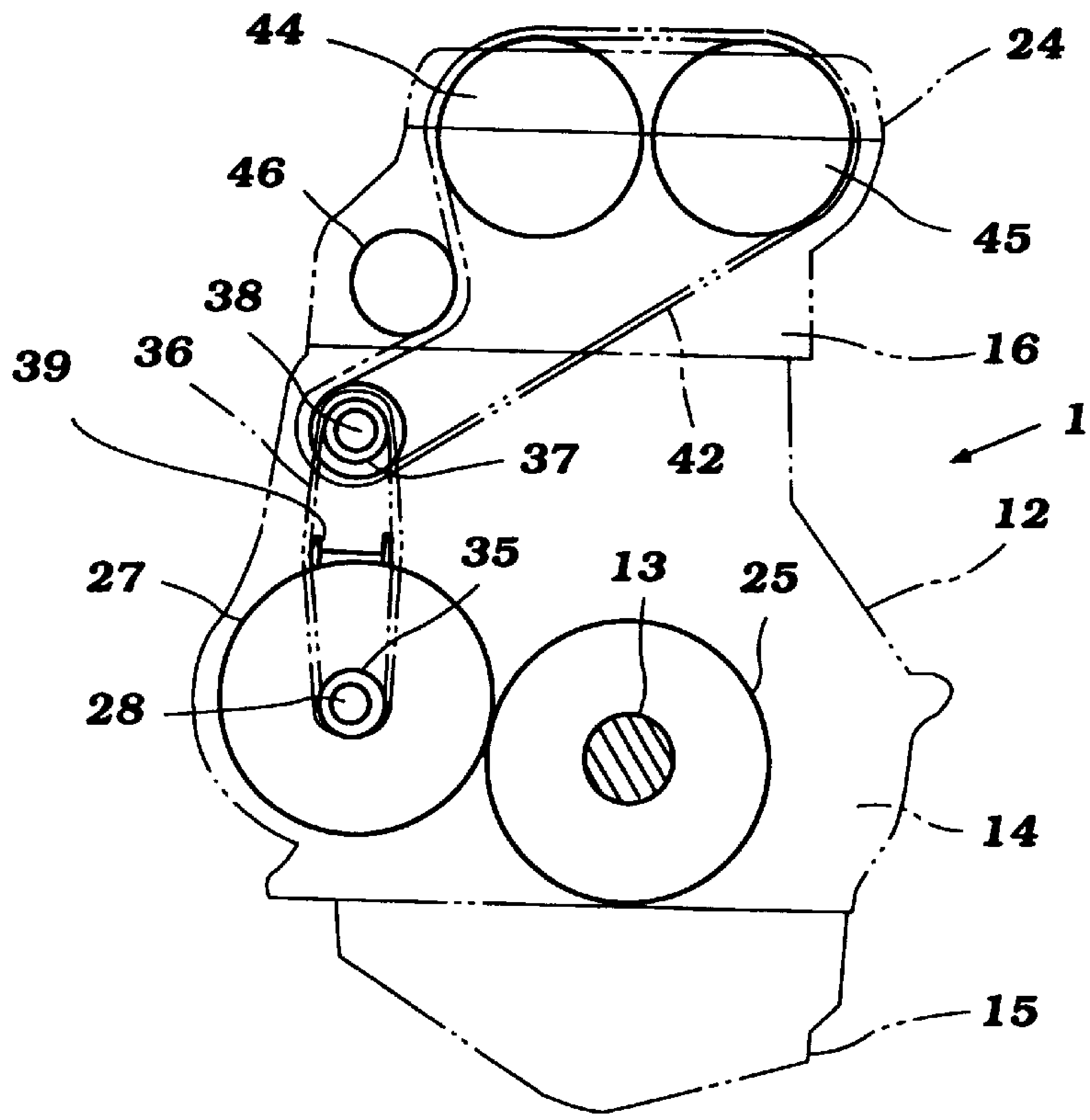

Figure 2

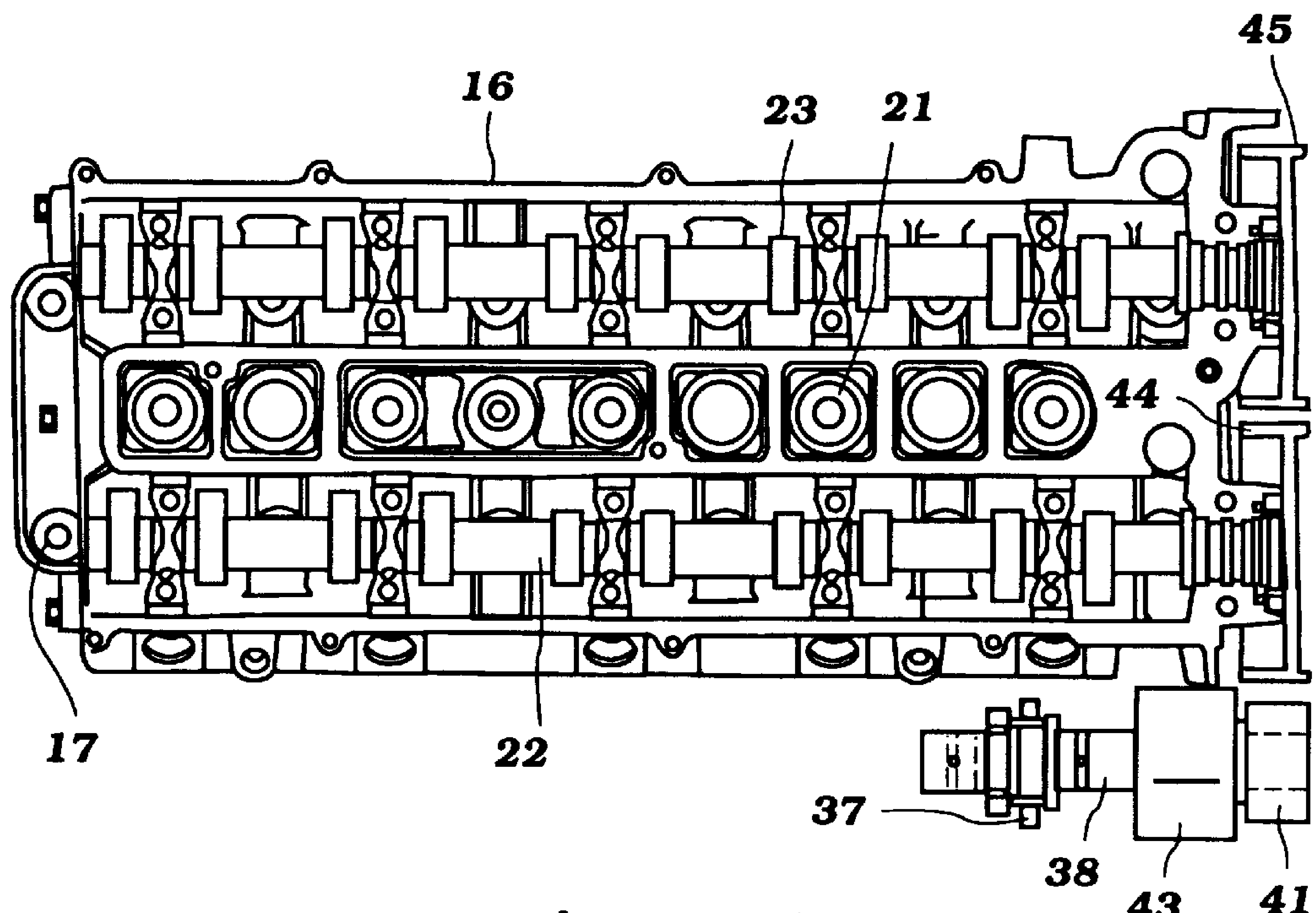

Figure 3

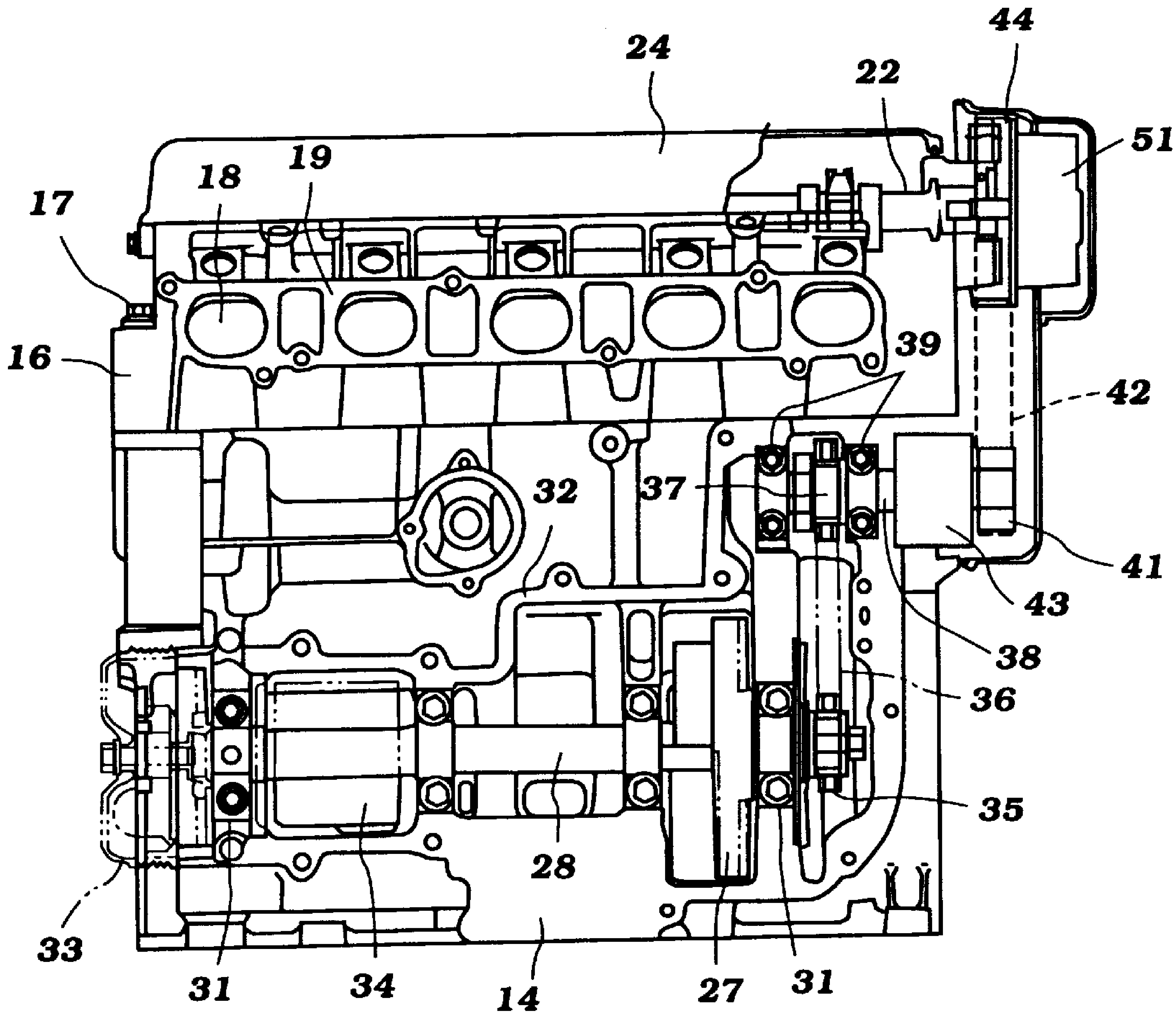

Figure 4

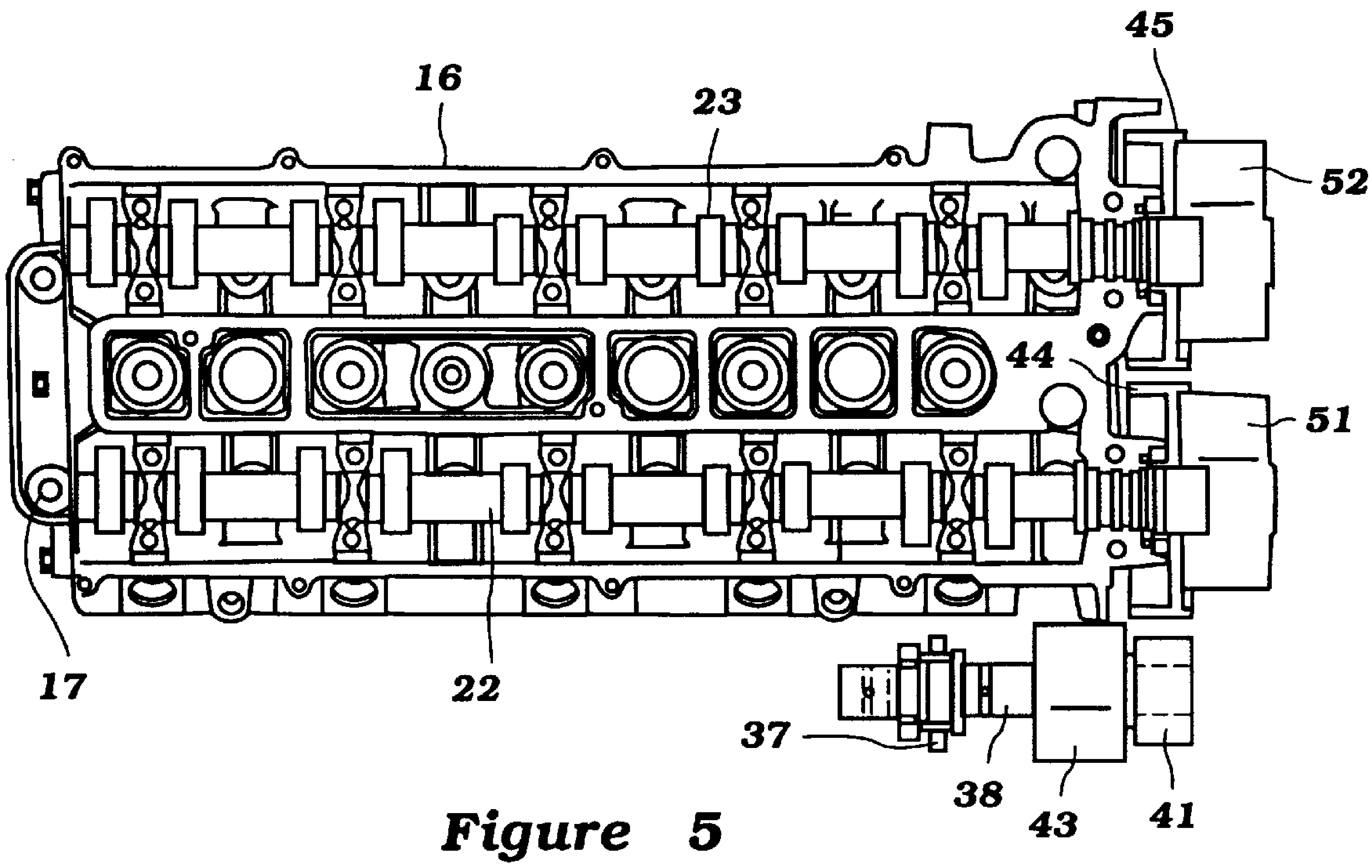

Figure 5

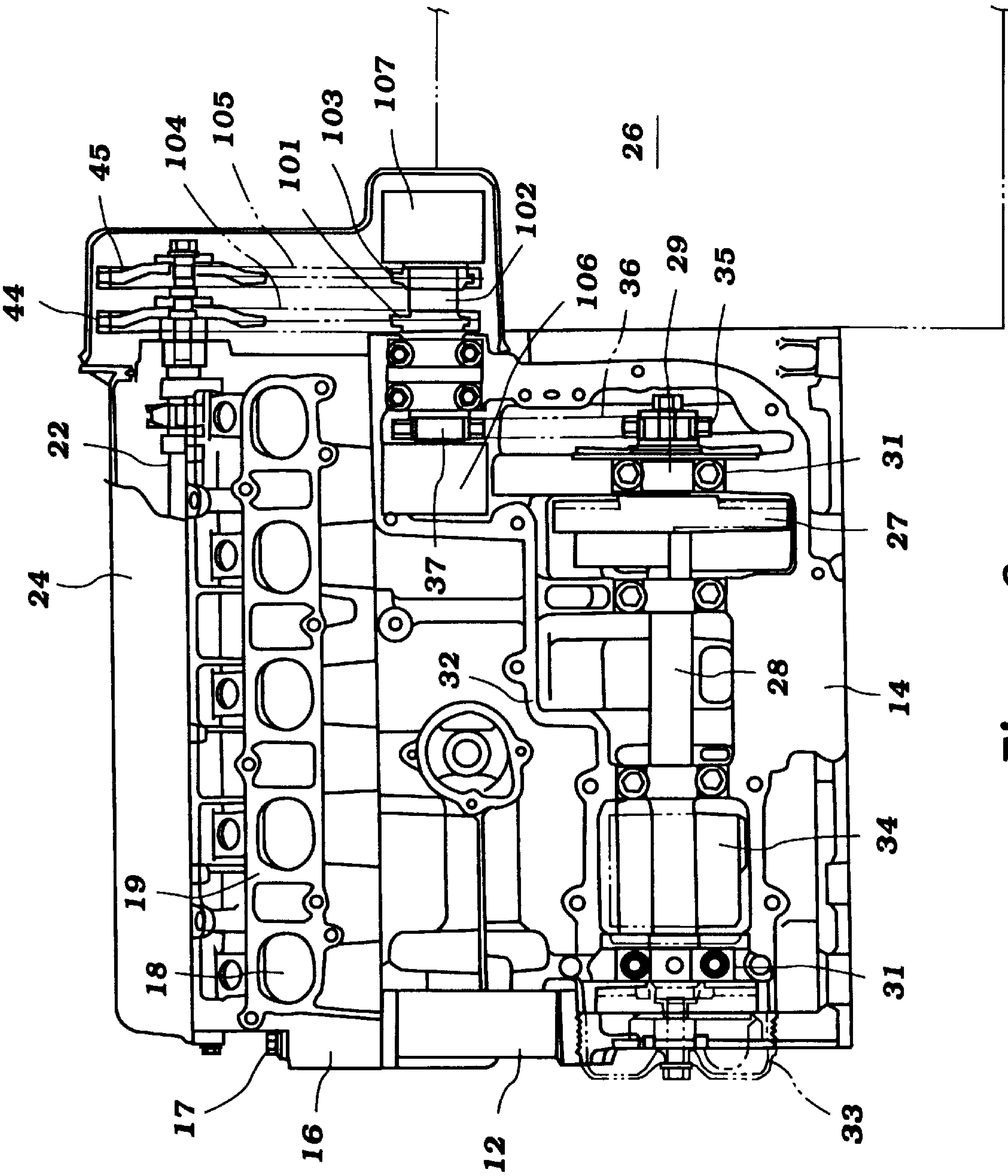
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Figure 6

CAM SHAFT DRIVE FOR ENGINE

BACKGROUND OF THE INVENTION

This invention relates to an internal combustion engine and more particularly to an improved cam shaft drive for such engines employing a variable valve timing mechanism.

In order to improve the flexibility of internal combustion engines and to provide a more desirable power curve, it has been proposed to employ a variable valve timing mechanism. By varying the phase angle of one or both cam shafts, it is possible to obtain optimum valve events for most running conditions of the engine.

The conventional type of variable valve timing mechanism (VVT) is normally positioned in the connection between a driving element mounted on the cam shaft and the cam shaft itself. These VVT mechanisms employ a hydraulically operated mechanism that shifts the phase angle of the cam shaft from its driving element, normally a sprocket.

Although the use of variable valve timing mechanisms has considerable advantages, the placement of the variable valve timing mechanism at the driving connection between the cam shaft and its driving element has some disadvantages. First, the variable valve timing mechanism has a fairly substantial size and thus, the overall length of the engine is generally increased through the use of VVT mechanisms. Also, when the mechanism is disposed in cantilevered fashion at the outward end of the cam shaft, there can be relatively high bending loads exerted on the cam shaft and heavy wear in the adjacent cam shaft bearing may result.

Also, the variable valve timing mechanisms are normally powered by the lubricant from the lubricating system of the engine. At times, this can present some problems in the delivery and return of the lubricating oil to and from the VVT mechanism.

It is, therefore, a principal object of this invention to provide an improved cam shaft driving arrangement for an engine.

It is a further object of this invention to provide an engine cam shaft driving arrangement wherein the cam shaft is driven by a variable valve timing mechanism that is not mounted at the end of the controlled cam shaft.

It is a further object of this invention to provide a variable valve timing mechanism that is interposed in the cam shaft driven in such a way as to minimize the size added to the engine.

SUMMARY OF THE INVENTION

This invention is adapted to be embodied in an internal combustion engine having an engine body that defines a combustion chamber and a cam shaft operated valving arrangement for controlling the admission of a charge to the combustion chamber and the discharge of a burnt charge from the combustion chamber. A piston reciprocates in the combustion chamber and drives an engine crankshaft. A timing driving drives the cam shaft from the engine crankshaft in timed relationship. This timing drive includes a variable valve timing mechanism for varying the phase relationship between the crankshaft and a cam shaft. The variable valve timing mechanism is located at a point that is displaced from the ends of the cam shaft.

In a preferred embodiment, the variable valve timing mechanism includes a component for varying the phase angle that is mounted on an intermediate shaft in the timing drive.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevational view of an internal combustion engine constructed in accordance with a first embodiment of

the invention, with certain components of the engine removed and other components broken away so as to more clearly show the construction.

FIG. **2** is a view looking generally in the direction of the arrow to in FIG. **1** and shows the cam shaft drive in solid lines and the remainder of the engine in phantom.

FIG. **3** is a top plan view of the engine with the cam cover removed and with a portion of the valve drive displaced so as to more clearly show this construction.

FIG. **4** is a side elevational view, in part similar to FIG. **1** and shows a second embodiment of the invention.

FIG. **5** is a top plan view of this embodiment and is, in part, similar to FIG. **3**.

FIG. **6** is a side elevational view, in part similar to FIGS. **1** and **3** and shows a third embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiment of FIGS. 1–3

Referring first to this embodiment, an engine constructed in accordance with it is identified generally by the reference numeral **11**. As should be apparent from the foregoing description, the invention deals primarily with the cam shaft drive arrangement for the engine **11**. Therefore, a number of the components of the engine which form no part of the invention such as the pistons, valves, etc. are not illustrated and will not be described in detail. Those skilled in the art will readily understand how the invention can be practiced with a variety of types of engines including engines having other cylinder numbers and other cylinder configurations from that described herein.

The engine **11** is comprised of an engine body that includes a cylinder block **12** in which a plurality of cylinder bores are formed. In this particular embodiment, there are five such cylinder bores. Pistons reciprocate in the cylinder bores and drive a crankshaft **13** that is rotatably journaled at the lower end of the cylinder block **12** within a crankcase chamber. This crankcase chamber is formed by a skirt **14** of the cylinder block and by an oil pan or crankcase forming member **15** that is attached thereto.

The pistons in the cylinder bores form combustion chambers along with the cylinder bores and suitably shapes combustion chamber recesses formed in a cylinder head assembly **16** that is affixed to the cylinder block **12** by means that include threaded fasteners **17**.

An intake manifold, which is not shown, cooperates to supply at least an air charge to these combustion chambers through a plurality of intake ports **18** formed in a side surface **19** of the cylinder head **16**. This intake manifold collects air from within the engine compartment, assuming the engine **11** is employed to power a motor vehicle as is a typical but not necessarily the sole environment in which the invention can be utilized. Throttle valves and other components are associated with this induction system.

An exhaust system (not shown) is affixed to the opposite side of the cylinder head **16** for discharging the burnt combustion products from the combustion chambers.

Spark plugs **21** (FIG. **3**) are mounted in the cylinder head assembly **16** and fired in a known manner for igniting a fuel air charge which has been admitted to the combustion chambers. Fuel is mixed with the inducted air by a suitable charge former which may include manifold or direct cylinder fuel injection.

Intake and exhaust valves open and close the intake passages **18** and the exhaust passages (not shown) for controlling the flow into and out of the combustion chambers. Since these valves may be of any known type, they are not illustrated.

However, the valves are operated by means of an actuating system that includes an intake cam shaft **22** and an exhaust cam shaft **23**. The intake and exhaust cam shafts **22** and **23** are journaled in the cylinder head assembly **16** in a known manner. This may include bearing surfaces formed directly in the cylinder head member **16** and bearing caps that are affixed thereto. The cam shafts **22** and **23** and the valve actuating mechanism are closed by a cam cover **24** that is affixed to the cylinder head **16** in any suitable manner.

As is well known, the cam shaft **22** and **23** are driven in a timed relationship with the crankshaft **23** at one half of crankshaft speed. This is to accommodate the four cycle operation of the engine **11**. This cam shaft timing drive includes a timing gear **25** that is fixed to the crankshaft **13** at a suitable location and preferably one that is located between the throws of the crankshaft associated with the first and second cylinders. These cylinders are counted beginning at the end of the engine shown in FIG. **2** and at the right hand side of FIG. **1**.

It should be noted that this orientation of the engine **11** is chosen so as to provide a transverse mounting of the engine **11** the engine compartment of an associated motor vehicle. This permits the driving of the vehicle through a transmission **26** that is driven off of the crankshaft **13** in this suitable manner.

Although the application of the engine **11** to powering a motor vehicle is a normal embodiment in which the invention is utilized, it should be readily apparent to those skilled in the art that the invention can be utilized with any of a wide variety of types of engine applications, particularly where a compact engine construction is required as well as an output that is optimum under substantially all engine running conditions.

Continuing to refer to the drive for the cam shafts **22** and **23**, the crankshaft timing gear **25** is enmeshed with a balancer shaft timing gear **27** that is affixed to a balancer shaft **28**. The balancer shaft **28** is journaled in one side of the cylinder block **12** by spaced bearing surfaces that are formed integrally therein and to which bearing caps **29** are affixed by threaded fasteners **31**. It should be noted that this balancer shaft **28** is mounted within a cavity in one side of the cylinder block **12** that is surrounded by a flange **32**. A suitable cover plate, which is removed in FIG. **1**, is mounted over an and encloses this mechanism.

The balancer shaft **28** does not extend beyond the end of the engine **11** where the cam shaft timing drive is located. This is to afford a compact construction.

If desired, the opposite end of the balancer shaft **28** may have affixed to it a drive pulley **33** for driving a plurality of accessories. A balancer mass **34** is also affixed to the balancer shaft **28** so as to assist in engine balancing.

The balancer shaft **28** has a drive sprocket **35** affixed to its end opposite the end where the accessory drive pulley **33** is located. This drive sprocket **35** is contained within the engine body and thus may drive a chain **36**. Although a chain drive is described, it should be apparent to those skilled in the art that other types of flexible transmitters or timing drives can be employed in this relationship.

The timing chain **36** drives a timing sprocket **37** that is affixed to a cam driving shaft **38** which is journaled at the same side of the cylinder block **12** and at the upper end of the recessed bounded by the flange **32**. This cam driving shaft **38** is also mounted by bearings formed in the cylinder block **12** and bearing caps that are affixed thereto by threaded fasteners **39**. As may be seen in FIG. **2**, a suitable tensioner mechanism **39** may be provided to act on the timing chain **36** to maintain the desired tension in this flexible transmitter drive.

Extending outwardly beyond the right hand end of the engine **11**, there is provided a further driving sprocket **41** which is also formed with teeth for ensuring a positive drive. At this location, however, a drive belt **42** is driven by the sprocket **41**. Although the invention is described in conjunction with a belt drive at this location, it should be readily apparent to those skilled in the art that other forms of timing drives may be employed including those using a chain.

The driving sprocket **41** is not driven directly by the cam driving shaft **38**. Rather, however, a variable valve timing mechanism, indicated generally by the reference numeral **43** and which may be of any known type is interposed in this drive. This variable valve timing mechanism **43** functions so as to shift the phase angle between the crankshaft **13** and the cam shafts **22** and **23**.

The flexible transmitter **42** is enmeshed with a pair of driven sprockets **44** and **45** which, in this embodiment, are fixed to the ends of the intake and exhaust cam shafts **22** and **23**, respectively. An idler or tensioner pulley **46** engages the back side of the transmitter **42** so as to maintain the appropriate tension in it.

Thus, it should be seen that in this embodiment, the variable valve timing mechanism **43** is disposed at a spaced location from the ends of the cam shafts **22** and **23** and inboard of the outer periphery of the engine so as to avoid any undue lengthening of the engine **11**. Also, the inboard location facilitates the delivery of lubricant from the engine lubricating system to the VVT mechanism **43** for its actuation. Any suitable control valve arrangement and location can be employed for operating this mechanism in accordance with any desired strategy.

Embodiment of FIGS. 4 and 5

In the embodiment as thus far described, there has been provided one variable valve timing mechanism, the mechanism **43** that is interposed in the connection between the cam driving shaft **38** and the drive sprocket **41** associated therewith. Because of this, the timing phase change between the crankshaft **13** and the cam shafts **22** and **23** will be the same. Although this is acceptable for many engine applications, it may be desirable to be able to provide independent adjustment of the timing of the two cam shafts **22** and **23**.

FIGS. **4** and **5** show such an embodiment. In this embodiment, however, the variable valve timing mechanism **43** and the drive as thus far described is again repeated. Because of that, components which are the same or substantially the same have been identified by the same reference numerals and will be described again only insofar as is necessary to permit those skilled in the art to understand and practice the invention of this embodiment.

In this embodiment, each of the cam shafts **22** and **23** is driven from its respective driven sprocket **44** and **45** through a respective variable valve timing mechanism, indicated by the reference numerals **51** and **52**, respectively. However, since the major portion of the phase shift may be made in and by the variable valve timing mechanism **43**, these VVT mechanisms **51** and **52** may be smaller than those normally employed wherein all of the phase shift must be accomplished in one mechanism.

Thus, although this embodiment does not have all of these advantages of the embodiment of FIGS. **1–3**, it does permit a compact engine construction than the prior art type arrangements where all of the phase reduction is accomplished by a single VVT mechanism at the end of the respective cam shaft.

Embodiment of FIG. 6

FIG. **6** shows an embodiment wherein the timing phase of the cam shafts **22** and **23** may be made completely independently of each other. In this embodiment, however, this is accomplished by utilizing VVT mechanisms that are spaced from the ends of the two cam shafts and not directly located at the cam shafts as with the embodiment of FIGS. **4** and **5**.

This embodiment also uses the cam driving shaft **38** that is driven from the balancer shaft in the manner already described. However, in this embodiment, the driving sprocket **37** of the intermediate shaft is coupled to a pair of quill shafts one of which carries an intake cam shaft driving sprocket **101** and the other of which, indicated by the reference numeral **102** which drives a cam driving sprocket **103** for the exhaust cam shaft. Thus, the intake and exhaust cam shafts are still driven by the sprockets **44** and **45**, respectively but through separate chains **104** and **105**.

Suitable variable valve timing mechanisms **106** and **107** are interposed between the driving sprocket **37** and the cam driving sprockets **101** and **103**, respectively. Thus, the phase angle of the sprockets **101** and **103** can each be controlled independently by their respective VVT mechanisms **106** and **107**, respectively. However, the upper portion of these engine is not significantly elongated because of the remote location of the VVT mechanisms.

Thus, from the foregoing description it should be readily apparent that the described embodiments of the invention provide a very effective VVT mechanism for an internal combustion engine and one which permits a compact engine construction and facilitates the control and supply of actuating fluid to the VVT mechanism. Of course, the foregoing description is that of preferred embodiments of the invention. It will be readily apparent to those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of the invention, as defined by the appended claims.

What is claimed is:

1. An internal combustion engine having an engine body defining at least one combustion chamber in which a piston reciprocates for driving a crankshaft for rotation about a crankshaft axis that extends longitudinally of said engine body, a valve mechanism for controlling the admission of a charge to said combustion chamber and the discharge of a burnt charge from said combustion chamber, said valve mechanism including at least one valve operating shaft, said valve operating shaft being journaled for rotation about a rotational axis that extends parallel to said crankshaft axis, a timing drive for driving said valve operating shaft in timed rotation from said crankshaft comprising at least one intermediate shaft directly driven by said crankshaft through a first drive and driving said valve operating shaft through a second drive, said timing drive including a variable valve timing mechanism disposed in the driving connection between one of said first and second drives and said intermediate shaft for varying the phase angle between said crankshaft and said valve operating shaft, said variable valve timing mechanism being disposed at a location that is spaced from the ends of said valve operating shaft.

2. An internal combustion engine having as set forth in claim **1**, wherein the variable valve timing mechanism is spaced transversely from the rotational axis of the valve operating shaft.

3. An internal combustion engine having as set forth in claim **1**, wherein the engine body includes a cylinder block and a cylinder head detachably connected thereto, the valve operating shaft being journaled in said cylinder head and the variable valve timing mechanism being located within said cylinder block.

4. An internal combustion engine having as set forth in claim **3**, wherein the intermediate shaft is journaled at an upper portion of the cylinder block adjacent the cylinder head and at one side of the said cylinder block.

5. An internal combustion engine having as set forth in claim **1**, wherein the first drive includes a balancer shaft driven by the crankshaft and driving the intermediate shaft.

6. An internal combustion engine having as set forth in claim **1**, further including a second variable valve timing mechanism interposed between the intermediate shaft and the valve operating shaft for varying the phase angle between said intermediate shaft and said valve operating shaft.

7. An internal combustion engine having as set forth in claim **1**, wherein the valve operating shaft comprises a pair of cam shafts each operating at least one respective intake and exhaust valve and the phase angle between the crankshaft and each of the cam shafts is adjusted by a variable valve timing mechanism.

8. An internal combustion engine having as set forth in claim **7**, wherein a single variable valve timing mechanism varies the phase angle between the crankshaft and the cam shafts.

9. An internal combustion engine having as set forth in claim **8**, wherein the variable valve timing mechanism is spaced transversely from the rotational axes of both of the cam shafts.

10. An internal combustion engine having as set forth in claim **8**, wherein the engine body includes a cylinder block and a cylinder head detachably connected thereto, the cam shafts being journaled in said cylinder head and the variable valve timing mechanism being located within said cylinder block.

11. An internal combustion engine having as set forth in claim **8**, wherein the second drive drives both of the cam shafts.

12. An internal combustion engine having as set forth in claim **11**, wherein the engine body includes a cylinder block and a cylinder head detachably connected thereto, the cam shafts being journaled in said cylinder head and the variable valve timing mechanism being located within said cylinder block.

13. An internal combustion engine having as set forth in claim **12**, wherein the intermediate shaft is journaled at an upper portion of the cylinder block adjacent the cylinder head and at one side of the cylinder block.

14. An internal combustion engine having as set forth in claim **11**, wherein the first drive includes a balancer shaft driven by the crankshaft and driving the intermediate shaft.

15. An internal combustion engine having as set forth in claim **12**, further including second and third variable valve timing mechanisms each interposed in the driving connection between the second drive and the respective cam shaft.

16. An internal combustion engine having as set forth in claim **12**, wherein there are a pair of variable valve timing mechanisms, each interposed between a respective second drive and one of the cam shafts.

* * * * *